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Research Experiences for Undergraduates (REU) Site
Integrating Research in Sustainable Energy and the Environment across Disciplines (IR-SEED)

Texas A&M University-Kingsville

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Research Project List

Project #1: Assessment and Optimization on the Supply of Renewable Energy for Electric Vehicles
By Dr. Francisco Haces Fernandez, Assistant Professor, Dept. of Management, Marketing and Information Systems

i. Motivation: Electric Vehicles (EV) are considered as one of the main strategies to reduce mobile source air pollution all over the world, while additionally generating significant financial savings in fuel consumption. However, attempting to charge millions of new EV with existing electric grid infrastructure could overload the system or continue generating air pollutants if traditional electric generators are used. Supplying EV with electricity from renewable energy will help offset these challenges while generating a number of important synergic financial and environmental benefits.

ii. *Project Description*: Locations that have optimal conditions for the harvesting of wind and solar energy are limited. Additionally, the placement of wind and solar energy equipment that will be used to supply EV needs to consider factors such as equipment type, layout distribution, proximity to major highways, peak traffic times, proximity to overnight parking areas and vehicle concentration. Two options need to be considered to charge EV: (1) public Electrical Vehicle Charging Stations (EVCS) or (2) work and residential parking chargers. Each charging option requires diverse methodologies and analysis when evaluating the implementation of renewable energy. The main research objective is the assessment and optimization of the placement and logistic of renewable energy harvesters in the United States to supply EV considering the two charging systems previously described. Data analytics and Geographic Information Systems (GIS) methodologies will be applied to assess wind and solar potential locations that are accessible to parking areas and to important highways. This project's four major research activities are: 1) Collecting meteorological data required to assess wind and solar power in diverse geographical locations 2) Collecting GIS data on major highways, vehicular traffic, vehicular parking for overnight and during work hours, population density and other data required to calculate electricity demand for EV. 3) Developing algorithms to evaluate and optimize wind and solar power output per location based on meteorological big data. 4) Calculating power consumption for EV considering diverse charging setting and during different periods.

iii. *Undergraduate Research Opportunities*: Two undergraduate students will participate in this project to conduct different research activities. Both students will work together to 1) collect and analyze meteorological data (wind and solar), 2) train on GIS and data analytics to evaluate optimal siting locations for renewable energy harvesters. One student will focus on learning to 1) calculate the electricity demand for EVCS over diverse time-periods and geographic locations and 2) Assesing and optimizing the best siting locations for renewable energy installations capable of satisfying EVCS demand. The second student will 1) calculate electricity demand for domestic and office parking spaces over diverse time-periods and geographic locations and 2) Assessment and optimization the best siting location for renewable energy installations capable of satisfying domestic and office parking spaces demand.

Project #2: Cybersecurity Threat Modeling and Defense for Photovoltaic (PV) Systems

By Dr. Taesic Kim, Assistant Professor, Dept. of Electrical Engineering and Computer Science

i. Motivation: According to the International Energy Agency, solar energy was the fastest-growing source of global energy in 2017. Performance of the conventional photovoltaic (PV) systems is limited by the on-board embedded systems in the solar inverters. Moreover, an expensive supervisory control and data acquisition (SCADA) system is still required for intelligent operation and maintenance of the PV systems. However, there are critical concerns and challenges about cybersecurity of the current PV systems. Cyber-attacks targeting the PV systems will impose new security and safety risks, specifically, maliciously intending to damage or disable PV systems. It is expected that the conventional PV system can be advanced as a result of further investigation of the emerging cyber-physical systems (CPS) such as Internet of Things (IoT), cloud/edge computing services, artificial intelligence (AI), and blockchain.

ii. Project Description: The objective of the proposed project is to investigate a cybersecurity framework for PV systems for improved situational awareness, cybersecurity, and privacy-preserved transactive control toward a smarter PV system in a smart grid environment. The approach is to: 1) investigate vulnerabilities and potential cyber-attacks; 2) design a smart inverter incorporating an IoT device; 3) design PV system grid simulation model; 4) build a cyber-physical security testbed using penetration testing tools; and 4) study and implement intrusion detection algorithms; and mitigation methods.

iii. Undergraduate Research Opportunities: Two undergraduate students will have an extensive experience in the state-of-the-art cybersecurity technologies and PV system research by participating in specific research tasks selected by students among the research activities under the guidance of Dr. Kim and Kim's research team including a post-doctorate research associate and graduate students. Students will: 1) learn knowledge of power system, cybersecurity attack and defense tools, IoT, and programming languages such as Matlab/Simulink, Java and Python; 2) have a hand-on experience in laboratory techniques such designing and testing smart inverters and IoT devices, and a hardware-in-the-loop (HIL) testing using a real-time grid simulator; and 3) participate in the dissemination activities.

Project #3: Development of a 2nd Generation Bionic Hand / Soft Grasping System

By Dr. Larry Peel, Professor, Dept. of Mechanical and Industrial Engineering

i. Motivation: Some people are born without a hand, or lose one. Current prosthetic hands are typically un-powered. A powered prosthetic hand could provide increased lifting/grasping/strength capabilities. Also, powered soft grasping devices are needed for robotic fruit picking, assistive devices for the elderly, and for other delicate, but firm-gripped needs.

ii. Project Description: Previous undergraduate, graduate, and faculty researchers at TAMUK have conducted considerable work on flexible actuators, and have fabricated a first-generation bionic hand. Typical rubber muscle-like actuators only need to contract, and commonly use braided mckibben-like or pleated structures. Finger-like actuators also need to bend as well as contract. Balloon-type actuators rely solely on fluid pressure over an area to produce force or torque, and need high and perhaps unsafe levels of pressure to produce significant levels of force in a bending actuator on the scale of a human finger. Mckibben or pleated actuators, where the pleats are along the long axis of a cylindrical actuator, rely on the inextensibility of fibers coupled with radial expansion of extensible membranes or pleats to produce 20 to 50 times the force of an equivalent pneumatic cylinder with the same pressure and diameter. Bending, and producing significant torque while bending, can be accomplished by adding tailored transversely stiff regions to certain areas of these rubber muscle actuators. It is felt that pleated rubber muscles are just a sub-set of McKibben actuators, and could be used to develop even more powerful Bending Rubber Muscle Actuators (BRMA). The major research activities will include: 1) Conduct literature searches on recent McKibben-like and Pleated flexible actuators, both theory, constitutive materials, and fabrication methods, especially since 2012. 2) Take existing Rubber Muscle Actuator (RMA) and Pleated Rubber Muscle Actuator (PRMA) models, and compare them to determine if the PRMA at the same diameter and pressure, will produce more contractive force. 3) Develop a simple Excel-based model to predict the torque or transverse force that a BRMA or a BPRMA would exert, given an initial diameter, length, stiffener width, pressure and braid angle, 4) Design a new BRMA or BPRMA about the size of a human finger, 5) Explore new fabrication methods and materials, especially using FDM-type 3D printing for fabricating several BRMA and/or BPRMA 'fingers'. 6) Fabricate and test a bionic hand to demonstrate the viability of the designs and predictions, 7) Document results.

iii. Undergraduate Research Opportunities: Two undergraduate students will participate in this project to conduct different but related research activities. One student will focus on learning 1) how a Rubber Muscle Actuator works and its fabrication, and how it can be turned into a Bending RMA, 2) Design the fingerless 'hand" for the "Bionic Hand 2" including all tubing, valves, connectors, etc, 3) Fabricate the fingerless hand using 3d printers, 4) Aid in the assembly and testing of a completed Bionic Hand 2, 5) Help document work. The other student will focus on learning 1) how a Pleated Rubber Muscle Actuator works and its fabrication, and how it can be turned into a Bending Pleated RMA, 2) Design the bending fingers for the "Bionic Hand 2" with associated connectors, etc, 3) Fabricate the fingers with 3d printers, 4) Aid in the assembly and testing of a completed Bionic Hand 2, 5) Help document work. The faculty research mentor, and any associated graduate students will conduct the rest of the activities listed in Section ii, and will work closely with the two undergraduate students.

Project #4: Design and Optimization of a Self-Adjustable Wave Energy Converter

By Dr. Hua Li, Professor, Dept. of Mechanical and Industrial Engineering

i. Motivation: Ocean wave energy resource potential is vast, and it can significantly contribute to the human energy needs if efficiently explored. However, the commercial harvesting of wave energy is still at infancy when compared to wind and solar energy. A wave energy converter needs to be able to optimally harvest wave energy and survive the harsh ocean environment at the same time. Of the different types of available wave energy harvesting methods, one promising concept is the heaving point absorber where the heave motion due to the interaction between ocean wave and absorber's body generates power. To harvest more energy, the heaving point absorber needs to operate at the resonance region during its interaction with the ocean waves to achieve the optimum oscillation, which is the main challenge with this concept due to the irregular frequencies of the real ocean waves.

ii. Project Description: This research seeks to design and optimize a self-adjusted wave energy converter based on heaving point absorber concept that is capable of harvesting wave energy optimally at multiple frequencies and is able to survive the ocean environment during its operating and design life at the same time. Theoretical hydrodynamic and diffraction of floating bodies, computational fluid dynamics, and finite element analysis tools as well as relevant design codes of practice will be applied to determine the device power capture rate, stability, static, and its fatigue responses using real ocean wave data from the Gulf of Mexico. There are three main tasks: 1) Improve an existing conceptual design of a self-adjusted WEC based on heaving point absorber concept through the optimization of its working mechanism, 2) Simulation and estimation of the energy capture of the self-adjusted WEC through the use of computational fluid dynamics and finite element analysis tools, and 3) Perform a structural reliability analysis of the self-adjusted WEC to ascertain its survivability in the ocean environment.

iii. Undergraduate Research Opportunities: Two undergraduate students will participate in this project to conduct different but related research activities. Both students will first work together to improve the existing design of a self-adjustable WEC. One student will focus on simulation and estimation of the energy capture of the new WEC. The other student will focus on structural reliability analysis of the new WEC.

Project #5: Estimating Effects of Land Use Change on Water Availability using Remote Sensing and Hydrologic Modeling

By Dr. Tushar Sinha, Associate Professor, Dept. of Environmental Engineering

i. Motivation: Several studies have shown that urbanization or increase in impervious area lead to increased stormwater runoff peaks, runoff volume, and higher risk of soil erosion, thereby increasing chances of localized flooding. For instance, Yuan and Qaiser showed that even gradual urbanization and densification from low to high intensity urban development could result in 10 to 19% increase in the peak flow. Changes in land cover and vegetation dynamics can alter interception storage, evapotranspiration, soil moisture and streamflow. Thus, changes in land use directly affect water availability, particularly in semi-arid watersheds. Thus it is important to estimate effects of land use change on water availability to update local and regional water supply management plans, which are typically updated once in every five years.

ii. *Project Description*: The overall objectives of this project is to quantify the effects of land use change between 1996 and 2016 on water availability in two selected watersheds in Texas. To accomplish this objective, changes in the spatial extent of land use will be determined using remote sensing and GIS analysis while the effect on water availability will be estimated using a widely used hydrologic model. Specifically, four major research activities include: 1) Georeferencing satellite-based land use data and classifying different land use extent using remote sensing, 2) Quantifying changes in land use between 1996 and 2016 for two selected watersheds in Texas, 3) Implementing a hydrological model for the two selected watersheds in Texas, and 4) Estimating effects of land use changes on water availability in different months and seasons.

iii. *Undergraduate Research Opportunities*: Two undergraduate students will participate in this project to conduct different research activities. One student will focus on: 1) Learning GIS and remote sensing tools, and 2) Performing geospatial analysis and creating high quality maps. The other student will focus on: 1) Setting up a hydrologic model and calibrating it, and 2) Analyzing and comparing effects of land use change on water availability.

Project #6: Net Zero-Energy Residential Building Design and Optimization

By Dr. Xiaoyu Liu, Assistant Professor, Dept. of Civil and Architectural Engineering

i. Motivation: Buildings represent 39% of U.S. primary energy use. They are one of the heaviest consumers of natural resources and account for a significant portion of the greenhouse gas emissions that affect climate change. Residential buildings also account for 27% of the total electrical use and is ranked as the second-largest electricity consumer in the world. To limit the energy consumption and GHG emissions in buildings, a key approach, nearly zero energy building (nZEB), is introduced as the new building target. A nearly zero energy building or a net zero-energy building (nZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains which is to maintain a balance between energy demand and renewable energy supply. In general, the design of a nZEB consists of two strategies: minimizing energy demand by applying passive design strategies (e.g. building envelope, orientation, shading) and active design strategies (e.g. high efficient HVAC system, efficient lighting). Unlike the design of a traditional building, to minimize the energy needs and investment cost, massive design alternatives need to be compared. Building optimization paired with building energy simulation is a promising solution for evaluating many different design alternatives and obtaining the optimal solution for one or multiple given objective(s) while complying with constraints.

ii. Project Description: This project is to investigate an outcome originated affordable cost-effective design procedure while considering the market availability of materials for a nZEB residential building. The following tasks will be conducted. Task 1: Review the knowledge of designing a sustainable building and related standards. Determine the solar energy resource availability in Kingsville, TX. Task 2: Develop the outcome originated design procedure. Task 2: Develop a building energy model of a selected three-bedroom single house based on EnergyPlus/EDSL Tas Engineering. Task 3: Conduct optimization analysis based on the building energy model. Determine the best design alternative.

iii. Undergraduate Research Opportunities: Two REU students will participate and learn during the whole period of the proposed project. Expected learning experiences include 1) hands-on numerical study skills; 2) professional software operation; and 3) data analysis and presentation skills.

Project #7: Waste Woodchip Activation to Manufacture Activated Carbon for the Uptake of Aqueous-phase Sulfamethazine

By Dr. David Ramirez, Professor, Dept. of Environmental Engineering

i. Motivation: Waste materials such as woodchips can be used to manufacture activated carbon via optimized energy activation. Carbonization and physical activation will be employed to manufacture waste-derived activated carbon for the removal of sulfamethazine (SMN) from water streams. SMN is an antimicrobial drug from the sulfonamide group widely used for veterinary purposes. Most of this antimicrobial drug is partially metabolized by cattle and swine and is then released into the environment through excretion. SMN mixed in soil dissolves rapidly in water and imparts additional environmental impact to the surface water, sub-surface water or soil.

ii. ***Project Description***: New adsorbents from woodchips will be manufactured by energy efficient activation for its potential use in removal of SMN from aqueous streams. The research activities will include setting up an experimental apparatus using a 3-zone horizontal furnace for the combustion and activation processes. The manufactured activated carbon will be compared with the raw material in terms of physical properties such specific surface area and pore size distribution using a surface area and pore size analyzer. The effective removal of SMN in water by adsorption mechanism is affected by the adsorption competition of heavy metals such as copper. In addition, the water pH plays a major role in the adsorption competition of SMN and heavy metals on activated carbons. The objectives for the adsorption characterization of the manufactured activated carbon are 1) to quantify the reduction of the adsorption capacity of commercial and laboratory manufactured activated carbons for the adsorption of SMN under the presence of copper; and 2) to quantify the effect of pH on the removal efficiency of SMN using activated carbons.

iii. Undergraduate Research Opportunities: Two REU students will work together on this project. The undergraduate students will conduct the proposed research activities under the supervision of the faculty mentor. The undergraduate researchers will be trained on preparation of raw material and manufacture activated carbon using combustion and activation, and get hands-on training on characterization of the manufactured activated carbon using state of the art instrumentation for environmentally related applications.